6. Application of the harmonized land cover map

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6.1 Introduction

A harmonized land cover map for the bodies under the LRTAP Convention has become available, see Chapter 5. The CCE applied this map throughout its work on critical loads. This chapter describes a comparison between harmonized land cover map and the ecosystems in the NFC submission, the creation of a European background database of empirical critical loads for nutrient nitrogen, and the comparison of this background database with the empirical critical loads from the NFCs. Some preparatory steps were necessary to apply the harmonized map as it was made available by SEI. These steps are described in the first paragraph below.

Other use of the new land cover map, which is *not* further described here, is the application in the background database for modelled critical loads. Also several NFCs have requested and used the map for their submission.

6.2 Preparatory steps

Figure 6-1 shows an aggregated representation of the compiled European land cover map.

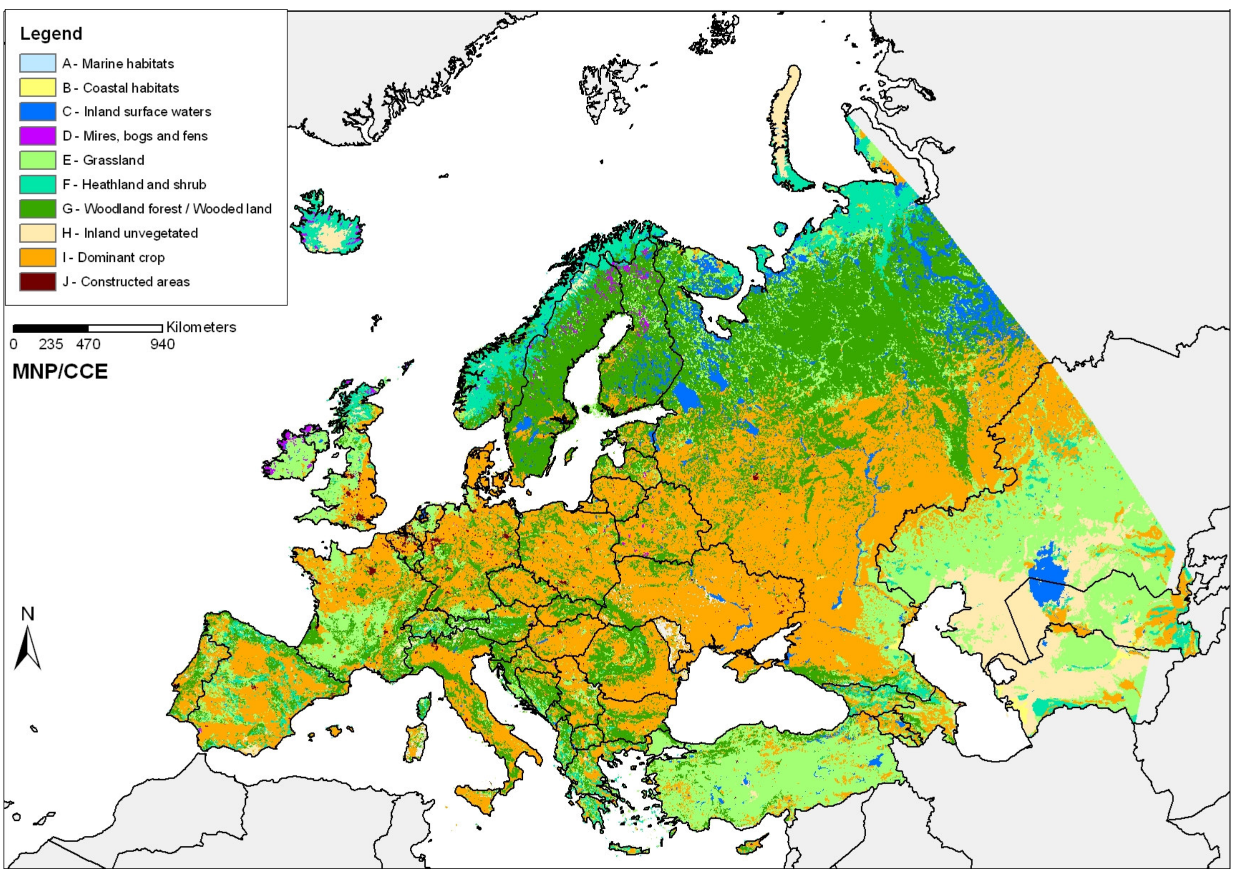


Figure 6-1. *The harmonized land cover map, aggregated to EUNIS level 1.*

For their map SEI used the land cover codes from the European Nature Information System habitat classification (EUNIS) (Davies et al., 2004). The EUNIS classification is a hierarchical typology of the habitats in Europe and its adjoining seas. The classes on the Land cover map mainly correspond to the second EUNIS level (e.g. D1, F1, etcetera). However, also vegetation types grouped to the first EUNIS level (e.g. B for all coastal habitats), combination of different EUNIS levels (e.g. A1 or A2 without A2.5), or a classification to the third EUNIS level were used. On the land cover map, forests (EUNIS class G) kept their former code version, but a preliminary classification to a third level EUNIS classes was in addition provided by S. Cinderby of SEI. The table in the annex 6-A to this chapter gives an overview of the EUNIS habitat classes distinguished on the SEI-map. Further preparatory (technical) steps include classification to singular EUNIS-codes, conversion to EMEP projection, clipping to countries borders and, in case of big countries, merging the parts in which the country were originally split. The resulting (100×100 m. grid) maps have been made available to the NFCs. The set of map of all European countries is hereafter referred to as the *(harmonized) land cover map.*

6.3 Comparing to the ecosystems of the NFC data

The comparison between the EUNIS-classes of the land cover map and the ones provided by the NFCs has been executed in two ways. Firstly, the point information of the NFCs has been compared with the polygon information from the SEI-map. Secondly, the compositions of EUNIS-classes in EMEP50-grid cells have been compared between the NFCs and the land cover map.

Comparison between NFC-ecosystems and land cover polygons

Until now most NFCs only produce critical loads for forest sites (EUNIS-code G). To make a meaningful comparison for most of the countries, we only considered the NFC forest sites. We analyzed for these NFC forest points, which EUNIS-classes are found on the SEI-map. We expected of course that the NFC forest points correspond to EUNIS-class G (forest) on the SEI-map. For this comparison we made a point in polygon overlay. For this we used the latitude and longitude information of the NFC forest sites. The EUNIS-codes of the land cover map were aggregated to the first level. Figure 5.2 shows that there is in general a large discrepancy between the NFC information and the land cover map information. For some countries like the Check Republic (CZ) the accordance is good (>90%), but for other countries like the United Kingdom (GB) it is poor (<20%).

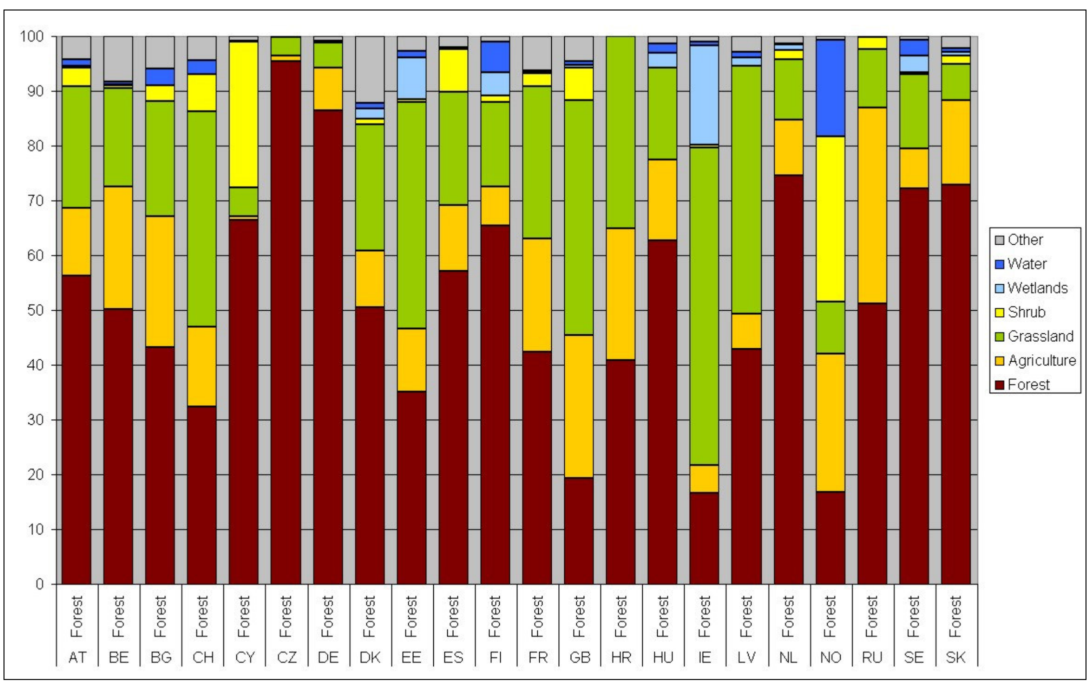


Figure 6-2. *Composition of EUNIS-classes of land cover map for NFC-forest points per country.*

Possible reasons for low agreement between the NFC forest site point information and EUNIS-classes from the land cover map could be:

- a NFC point (ecosystem) is in several countries the centroid of a polygon that may be clustered or somehow aggregated. The probability of this centroid to match the same land use class resembles the histogram of the harmonized map, especially for a submission based on a coarser map, and in a scattered region. (Compare the distribution of the total land cover classes of the countries in Figure 2-1 with Figure 6-2).

- Assigning classifications that originate from sources like Corine to EUNIS-classes can make the result fuzzy, for example the classes shrub (F) and forest (G) may overlap.
- NFC point co-ordinates are not always accurate (differences up to 10 km have been found).

Although the point-to-polygon comparison may show little accordance, a NFC submission could still represent the ecosystems in a region very well. To test this, the histograms of land use within each EMEP grid of the land use map are compared to the NFC submissions.

Comparison between histograms of NFC-ecosystems and the land cover map

A comparison of the composition of EUNIS-classes of larger areas between NFCs and the land cover map does not have the abovementioned drawbacks. Therefore, we compared the areas of different EUNIS-classes by EMEP50-grid cell. As already mentioned in the former section, most NFCs only produce critical loads for forest sites. To make a meaningful comparison for most of the countries, we compared the area of forests by EMEP50 grid cell between NFCs and the land cover map. We used the most *recent* NFC data submission for acidification (partly 2007). We used the Kappa-Histo-statistic as measure for correspondence. A high Kappa-statistic means a high similarity area of the EMEP50-grid cell between NFCs and the land cover map and vice versa. In Figure 6-3 the result of this comparison is depicted.

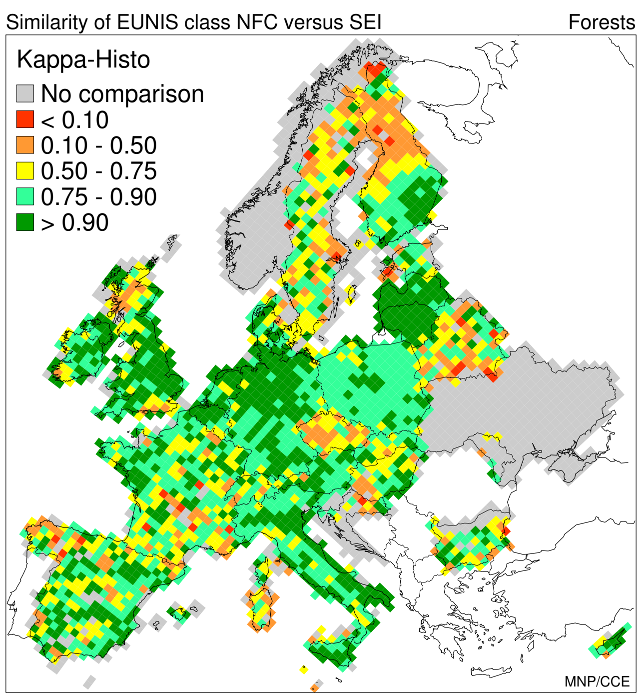


Figure 6-3 *Correspondence (Kappa-Histo statistic) in area forest per EMEP50-grid cells between NFCs and the land cover map.*

This map shows that for most countries the correspondence in area of forest is quite high, with exception of some areas like Scandinavia and the Czech Republic. Possible reasons for the low correspondence in these latter areas were investigated by studying both source maps for forest

(Figure 6-4). From this figure it is clear that the magnitude of the forest area differ but that the forest patterns look similar. In general the area of forests in the NFC-map seems to be higher then in the land cover map. A possible explanation for this may be that EUNIS-classes like shrubs (F) are included in the NFC-information.

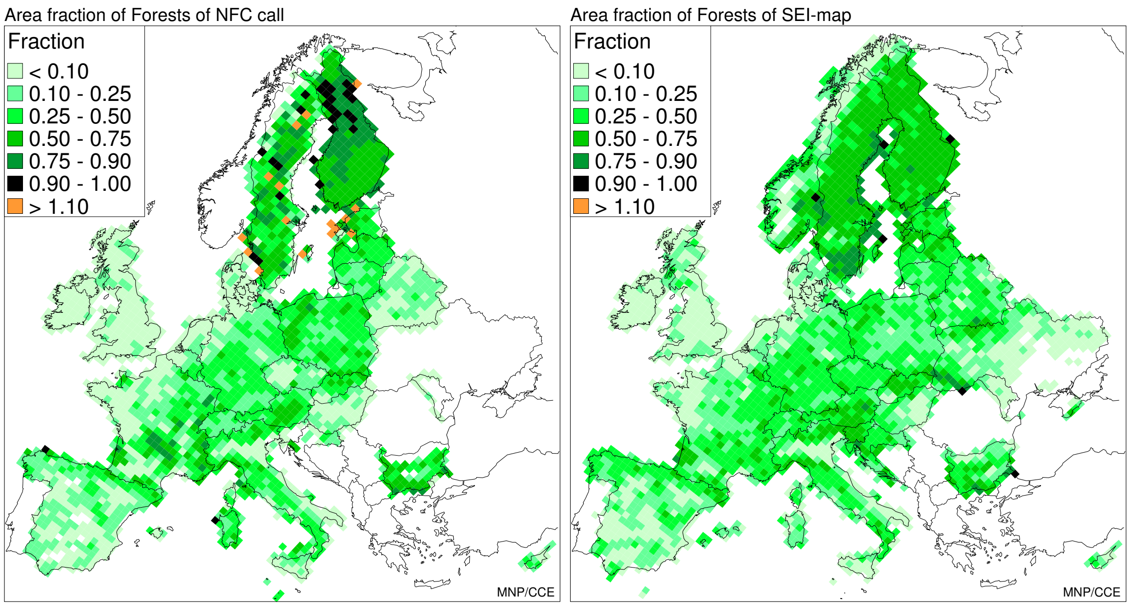


Figure 6-4. *Distribution of forest by EMEP50 grid cell, left: source NFCs, right: source land cover map.*

6.4 Adaptation of European empirical critical loads for EUNIS habitat classes of the land cover map

Existing and European empirical critical loads

Until 2006 the NFCs have calculated critical loads for acidity and eutrophication, mostly based on soil properties and steady-state mass balance methods (Posch et al., 2005). In the call of 2007, for the first time NFCs have also been asked to submit *empirical* critical loads for eutrophication. These empirical critical loads (*CLempN*) are based on Achermann and Bobbink (2003) and were derived from scientific studies or expert knowledge on the effects of long term (at least 2-3 years) increased nitrogen deposition on the structure and function of natural and semi-natural ecosystems. For the descriptions of ecosystems the EUNIS habitat classification (Davies et al., 2004) was used. The empirical critical loads are presented as ranges (in kg N $ha^{-1}a^{-1}$).

Not for all EUNIS habitat types *CLempN* are available, since no or not yet enough published scientific studies exist from which *CLempN* could be derived (Bobbink, personal comment 2007). No additional literature studies were conducted to fill gaps in missing *CLempN* values for other EUNIS codes. For forest systems Dorland and Bobbink (2005) prepared *CLempN* data, however these have to be approved yet in an expert workshop. During this project Dr. R. Bobbink was consulted to discuss possibilities for the application and differentiation of empirical critical load ranges.

Adaptation of empirical critical loads for EUNIS-classes to the land cover map

To convert the European empirical critical load data to the land cover codes distinguished on the land cover map (see chapter 5), four steps are recognized:

1. check consistency of used EUNIS codes on SEI-map;
2. check necessity and availability of empirical Critical Loads (*CLempN*) for EUNIS classes distinguished on the land cover-map;

3. analyse and study application of differentiation of the *CLempN* ranges according the general relationships mentioned in Achermann and Bobbink (2003);
4. analyse possibilities to adopt *CLempN* for present SEI-EUNIS codes without *CLempN*.

Check the consistency of applied EUNIS codes on SEI land cover map

In this first step the EUNIS codes and descriptions from the land cover map were compared with the EUNIS classification by Davies et al. (2004). On this land cover map EUNIS-codes were applied, except for forests and agricultural lands. In most cases second level EUNIS-codes or combinations of these codes were used, while for grasslands EUNIS-classes E1 and E2 combinations of third level codes were used. All coastal habitats are grouped to the first EUNIS class (B). Forest were coded on the land cover map according SEI codes from a former EUNIS version (1000 till 1072, 2000 till 2270 and 3000 till 3177), though those had already been preliminary grouped in second level EUNIS classes G1, G3 and G4 according to the most recent EUNIS classification. Agricultural land, other than grassland, was coded I1 by SEI with numbers 1-1031, of which the numbers refer to the dominant crop that was cultivated on the agricultural land. These agricultural codes were grouped for this project in EUNIS class I1 (Arable land and market gardens).

In this project two numeric classifications have been used to describe all present EUNIS codes on second and on third level in the Land cover map and in the data submitted by the NFCs. These classifications have to be created because the Land cover map contains also codes which are combinations of EUNIS classes, like ‘A3 or A4’. The classification on the second level makes it possible to compare the EUNIS-codes of the Land cover map with the EUNIS-codes in the NFC-dataset. The classification on the third level will be used for the assignment of empirical critical loads. Annex 6-A contains the overview of the classes in the second level and third level numeric EUNIS-classification present on the land cover map.

Check of necessity and availability of empirical critical loads for EUNIS-classes on the land cover map

To check the necessity and availability of *CLempN* for the EUNIS classes on the land cover map the following sources were used:

- The overview of the EUNIS codes on the land cover map (the result from Step 1);
- The report with the descriptions of the EUNIS classes by Davies et al. (2004);
- The overview with available *CLempN* per EUNIS class by Achermann and Bobbink (2003).

The EUNIS classes distinguished on the SEI land cover map are presented with the short habitat description in Table 6-1. For each of these EUNIS code the necessity for considering this habitat in CL analysis was evaluated by assessing the descriptions of the EUNIS class (Davies et al. (2004). E.g. the A3/A4 EUNIS class in the SEI land cover map is described as Infra- and Circalittoral rock and other hard substrata. These habitats are variable saline, dominated by kelp, seaweed or animals and variable influenced by wind, tidal streams and wave action. We considered that probably little effect of nitrogen enrichment via nitrogen deposition will occur in these habitat types. All Coastal habitats on the SEI land cover map are grouped in EUNIS class B. This class on the SEI map therefore combines among others the unvegetated coastal dunes and sandy shores, with coastal dune heaths and dune slacks, coastal shingles, soft and rock cliffs. For most classes, though not all (e.g. B1.1 and B3.2), CL analysis is recommended. However, this distinction is not possible on the SEI land cover map. EUNIS class C3 refers to littoral zones of inland surface water bodies. Nitrogen enrichment may also affect these habitats.

In Table 6-1 the necessity for CL analysis of each EUNIS habitat from the SEI map is represented; ‘-’ refers to the habitats for which CL analysis is not necessary (e.g. A3/A4); ‘+/-’ refers to habitat class for which part of the habitats are sensitive to nitrogen enrichment and should be considered in CL analysis (e.g. B); ‘+’ refers to habitats that are probably nitrogen sensitive and CL analysis are recommended (e.g. C3).

Table 6-1. *Overview of EUNIS vegetation classes distinguished on the SEI land cover map and information on necessity for CL analysis, availability and ranges of empirical Critical Load. Necessity for CL analysis and availability of CLempN is represented by: - = no; + = yes and +/- = for part of the EUNIS class. Bold black CLempN ranges are based on identical EUNIS classes reported by Achermann and Bobbink (2003), grey values represent CLempN (ranges) adopted from known CLempN information based on expert knowledge. In the most right column the source of the CLempN range and/or additional comments are represented (B2002: Achermann and Bobbink (2003) and EUNIS code).*

EUNIS CODES SEI MAP	SHORT DESCRIPTION (DAVIES *ET AL.* 2004)	NECESSITY FOR CL ANALYSIS	IS *CLempN* INFORMATION AVAILABLE	*CLempN* RANGE (KG N/HA.A) MIN	MAX	BASED ON / REMARK:
A1 or A2 without A2.5	Littoral rock/sediment and other hard substrata without A2.5	-	-			
A2.5	Coastal salt marshes and saline reed beds	+	+	**30**	**40**	B2002: A2.54; A2.55
A3 or A4	Infra- and Circalittoral rock and other hard substrata	-	-			
A3 or A4 or A5	Infra-, littoral rock, sediments and other hard substrata	-	-			
A5	Sublittoral sediment	-	-			
B	Coastal habitats	+/-	+/-	ND (10)	ND	
C1	Surface standing waters	+	+/-	ND (5)	ND	* *CLempN* class C1.1 (or C1.16) not representative for C1
C2	Surface running waters	+	-	ND	ND	* not enough background information
C1 or C2	Surface standing and running waters	+	+/-	ND (5)	ND	* *CLempN* class C1.1 (or C1.16) not representative for C1/ C2
C3	Littoral zone of inland surface water bodies	+	-	ND	ND	* not enough background information
D1	Raised and blanket bogs	+	+	**5**	**10**	B2002: D1
D2 or D4	Valley mires, poor fens, transition mires or base-rich fens, calcareous spring mires	+	+	**10** **15** **15**	**20** **35** **25**	B2002: D2.2; B2002: D4.1; B2002: D4,2
E1 without E1.2, E1.7, E1.8, E1.9, E1.A	Dry grasslands without E1.2, E1.7, E1.8, E1.9, E1.A	+	-	15	25	* all base-rich vegetation types; therefore *CLempN* adopted from B2002: E1.26
E1.2	Perennial grasslands and basic steppes	+	+/-	15	25	* variety of wetness in class E1.2; best estimate *CLempN* of subclass B2002: E1.26
E1.7 or E1.9	Non-Mediterranean dry acid and neutral grassland	+	+	**10**	**20**	B2002: E1.7; E1.94; E1.95
E1.8 or E1.A	Mediterranean dry acid and neutral closed/open grassland	+	-	15	20	* value adopted high value range temperate equivalent B2002: E1.7; E1.94; E1.95
E2 without 2.3	Mesic grasslands without E2.3	+	+/-	20	30	* value adopted from E2.2, though different habitats are represented by E2
E2.3	Mountain hay meadows	+	+	**10**	**20**	B2002: E2.3
E3	Seasonally wet and wet grasslands	+	+/-	ND (10)	ND	* trophic gradient in E3; *CLempN* E3.51 and E3.52 not appropriate for whole E3
E4	Alpine and subalpine grasslands	+	-	5	15	B2002: E4.2; E4.3; E4.4
E5	Woodland fringes and clearings and tall forb stands	+	-	ND	ND	* diverse vegetations affected by agriculture or saline influences
F1	Tundra	+	+	**5**	**10**	B2002: F1
F2	Arctic, alpine and subalpine scrub	+	+	**5**	**15**	B2002: F2
F4	Temperate shrub heathland	+	+	**10** **10**	**20** **(25) 20**	B2002: F4.11; B2002: F4.2
F5 or F6	Maquis, arborescent matorral and	+	-	ND	ND	* not enough background

EUNIS CODES SEI MAP	SHORT DESCRIPTION (DAVIES *ET AL.* 2004)	NECESSITY FOR CL ANALYSIS	IS *CLempN* INFORMATION AVAILABLE	*CLempN* RANGE (KG N/HA.A) MIN	MAX	BASED ON / REMARK:
	thermo-Mediterranean brushes or Garrigue					information
F9	Riverine and fen scrubs	-	-			
G2000..2279 (G1)	Broadleaved deciduous woodland	+	+	**10**	**20**	
G1000..1072 (G3)	Coniferous woodland	+	+	**10**	**20**	B2002: comb. forest layer, dependent on the process of interest
G3000..3177 (G4)	Mixed deciduous and coniferous woodland	+	+	**10**	**20**	
H3	Inland cliffs, rock pavements and outcrops	-	-			
H4	Snow or ice-dominated habitats	-	-			
H5	Miscellaneous inland habitats with no or sparse vegetation	-	-			
I1	Arable land and market gardens	-	-			
I2	Cultivated areas: gardens/parks	-	-			
J	Constructed, industrial and other artificial habitats	-	-			

In addition, the availability of empirical Critical Loads (*CLempN*) for the present EUNIS codes[3] on the SEI land cover map was examined. The empirical Critical Loads from Achermann and Bobbink (2003) were used. In Table 6-1 the availability of any *CLempN* information for this EUNIS habitat is represented by '+' (= available), '-' (= not available) or '+/-'; which refers to available *CLempN* information for part of the on the SEI map used EUNIS codes. When *CLempN* information is available for a EUNIS class that is identical to the EUNIS class distinguished on the SEI land cover map, the *CLempN* ranges are applied and reported in bold black figures in Table 6.1. For other classes *CLempN* information is available for only part of the EUNIS class from the SEI land cover map (e.g. a *CLempN* is known for the third level EUNIS, while second or first level EUNIS is on the SEI map). The *CLempN* from Achermann and Bobbink (2003) are often set to sensitive ecosystems and these systems are often only a small representative of the whole second or first level EUNIS class. Evaluation of the appropriate *CLempN* range for these EUNIS habitats form the land cover map and adoption of *CLempN* values is discussed in the following section. Besides, for some other EUNIS classes no *CLempN* are available from Achermann and Bobbink (2003).

Analysis and study of differentiation of the ranges

The third step describes the analysis and the study of the application of differentiation of the *CLempN* ranges according the general relationships, mentioned in Achermann and Bobbink (2003). They described several factors which may lead to differentiation within the *CLempN* ranges for non-wetland systems (EUNIS classes E, F and G; Table 6-2). There is not a specific order of importance for these factors (Bobbink, personal comment 2007), though the factors act at different scales. For differentiation of the *CLempN* ranges on a European scale not all factors can be used here. Management activities, or P limitation act on smaller, more local scales. For NFCs this specific information is or could be available and can be used by them. Other factors like temperature or base-

[3] Remark that the EUNIS table was revised and the version of 21-07-2005 was used in this report. The code A2.6 from Achermann and Bobbink (2003) coincides with A2.5 in the revised report.

cation availability are applicable on larger scales and can therefore be used to differentiate the ranges on European scale.

Table 6-2. *Overview factors differentiation CLempN range non-wetland systems (Achermann and Bobbink, 2003).*

Action	Temperature / frost period	Soil wetness	Base-cation availability	P limitation	Management intensity
Move to lower part	COLD/LONG	DRY	LOW	N-LIMITED	LOW
Use middle part	INTERMED	NORMAL	INTERMED	UNKNOWN	USUAL
Move to higher part	HOT/NONE	WET	HIGH	P-LIMITED	HIGH

Table 6-3. *Overview of differentiation of the available CLempN ranges for non-wetland systems cross the biogeographical regions (Cultbase, 2005). * For forests (G) a CLempN is available, though the height of the CLempN is dependent of the process.*

		Alpine North	**Boreal**	**Nemoral**	**Alpine South**	**Continental**	**Pannonic**	**Atlantic North**	**Atlantic Central**	**Mediterranean mountains**	**Mediterranean North**	**Lusitanian**	**Mediterranean South**
EUNIS class	gr. seas. (days)	130	157	196	220	227	250	255	296	298	335	353	363
D2 or D4		10-15					15-20						
E1 without E1.2, E1.7, E1.8, E1.9, E1.A		15-20					20-25						
E1.2		15-20					20-25						
E1.7 or E1.9		10-15					15-20						
E1.8 or E1.A						15-20							
E2 without 2.3		20-25					25-30						
E2.3		10-15					15-20						
E4		5-10					10-15						
F1						5-10							
F2		5-10					10-15						
F4		10-15					15-20						
G1 (2000..2279)		ND*											
G3 (1000..1072)		ND*											
G4 (3000..3177)		ND*											

To differentiate the *CLempN* range for non-wetland habitat across Europe by application of differences in temperature/frost period we propose to use biogeographical regions as a first step. From these biogeographical regions information (Cultbase, 2005) is available, among other on the length of the growing season, as a proxy for long winters and frost periods. Table 5-3 shows the different biogeographical regions with the average length of the growing season. The empirical critical loads are differentiated linearly in ranges of 5 kg $N \cdot ha^{-1} \cdot a^{-1}$ over the biogeographical regions according the length of the growing season. In general, this leads to a division of the range in two groups (Figure 6.5).

The subranges of 5 kg N $ha^{-1} \cdot a^{-1}$ were chosen, since no better accuracy can be obtained as several factors affect the *CLempN* for a specific habitat. A more accurate decision for differentiation could be made when several factors are used. On European scale application of base cation availability, in addition to temperature/frost period would enhance the decision for differentiation. For forests the *CLempN* are not divided in two subgroups, since the *CLempN* range of 10-20 is dependent on the (biological) process one focuses on for nitrogen sensitivity.

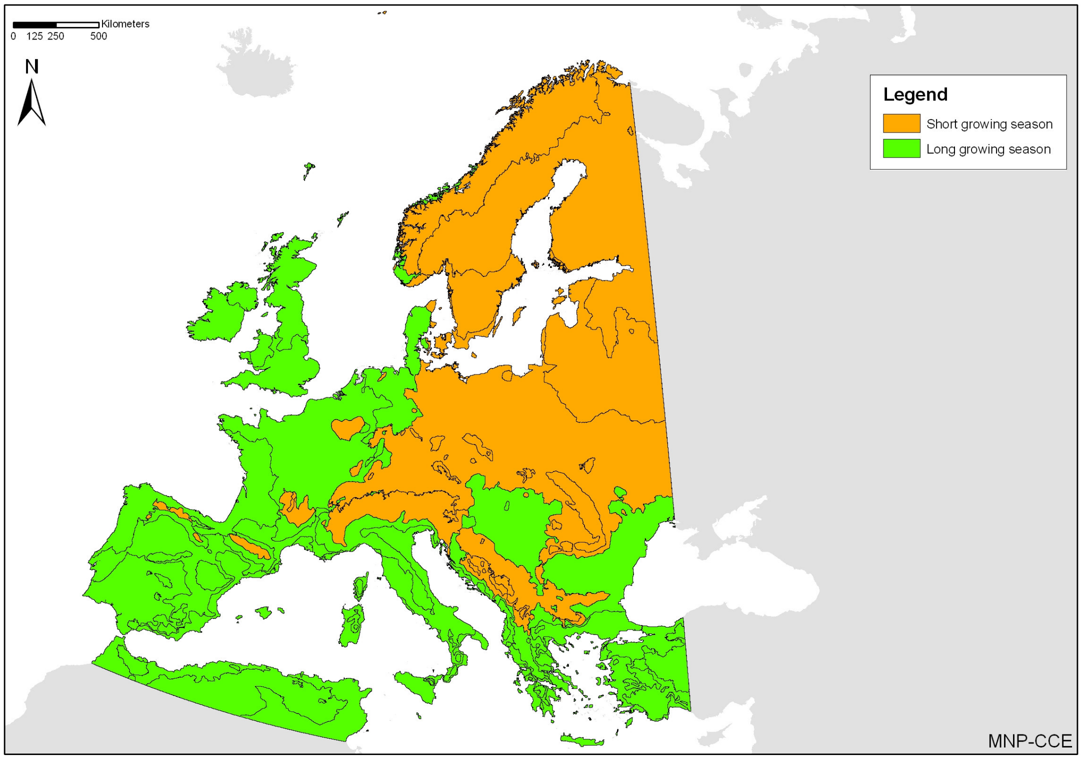


Figure 6-5. *Overview of two groups of biogeographical regions across Europe (Cultbase, 2005).*

Analysis of possibilities to derive missing *CLempN*

The last step is the analysis of the possibilities for derivation of missing *CLempN* for a number of SEI-EUNIS codes. From Table 2 it is clear that there exist gaps in the knowledge on the *CLempN* for almost all EUNIS classes. Achermann and Bobbink (2003) remarked that there is limited knowledge on the effects of enhanced nitrogen enrichment for specific habitat types, especially for steppe grassland, all Mediterranean vegetation types, wet-swamp forests, many types of mires and fens, several coastal habitats and high altitude systems. However, also for other vegetation types additional information is needed to be able to apply *CLempN* on the SEI-map.

For some EUNIS classes *CLempN* ranges are available, but also complications arise because on the SEI-map some EUNIS classes were grouped with other EUNIS classes for which no *CLempN* is available or necessary. Based on expert knowledge we filled the gaps by adoption of *CLempN* from comparable systems, or adopting the values from a third level EUNIS group within the EUNIS class. In adopting *CLempN* we apply the precautionary principle. From a conservation point of view it is recommended to apply the lowest *CLempN* available to protect also the more sensitive habitat types. Therefore, we advise to choose the lowest *CLempN* value. For each adopted value, the motivation is added below and shortly commented in Table 6-1.

Additional information on the assignation of *CLempN* ranges from Table 6-1 is given here:

Inland surface waters (EUNIS class C)

- We choose not to set a *CLempN* range for waters of C1. The known *CLempN* (Achermann and Bobbink, 2003) is only assigned to permanent oligotrophic waters (C1.1) and to a subgroup of these waters (C1.16). These water types are only a small representative of the whole C1 level, while other C1-waters have generally a higher nutrient availability. One could choose to set the *CLempN* range based on the most sensitive system (here C1.1), however this is probably a too low estimate for most waters. Setting a higher value for the C1 level would result in an inaccurate value for the waters within the C1 level belonging to C1.1.
- For surface running waters and the littoral zone of these waters, C2 and C3, respectively, no *CLempN* could be set due high variability of systems within these groups.

Mires, bogs and fen habitats (EUNIS class D)

- On the land cover map the grouped EUNIS classes ‘D2 or D4’ are distinguished. For both D2 and D4 *CLempN* information is available from scientific research. However, it is impossible to discriminate between D2 (poor fens) or D4 (rich fens) on the land cover map. Since many of these systems are vulnerable for N-enrichment, we suggest using the lowest *CLempN* range for the combined group.

Grasslands and tall forb habitats (EUNIS class E)

- On the SEI-map the EUNIS second EUNIS level E1 was split in the following classes: ‘E1 without E1.2, E1.7, E1.8, E1.9, E1.A’, ‘E1.2’, ‘E1.7 or E1.9’ and ‘E1.8 or E1.A’. Only for ‘E1.7 or E1.9’ *CLempN* information is available.
  - The subgroup of dry grasslands, ‘E1 without E1.2, E1.7, E1.8, E1.9, E1.A’ on the SEI-map consists mainly of base-rich soils. High base cation availability lowers the vulnerability for nitrogen enrichment (table 5.1). For E1.26, a subgroup of the base-rich groups within E1, a *CLempN* is known. Therefore, we adopt the *CLempN* of E1.26 for the whole ‘E1 without E1.2, E1.7, E1.8, E1.9, E1.A group’ on the SEI-map.
  - For E1.2, the *CLempN* from the E1.26 is the best estimate, therefore this *CLempN* was adopted.
  - The systems E1.8 or E1.A are Mediterranean equivalents of E1.7 or E1.9. For the latter systems a *CLempN* was set. In general Mediterranean systems have longer growing seasons and higher temperatures compared to temperate systems. Therefore nutrient turn-over rates are higher. The *CLempN* for the Mediterranean systems E1.8 or E1.A, distinguished on the SEI land cover map, was therefore set on the high end of the range of the *CLempN* for E1.7 or E1.9.
- The mesic grasslands grouped under ‘E2 without E2.3’ are often cultivated by men. They contain lowland and montane mesotrophic and eutrophic pastures and hay meadows of the boreal, nemoral, warm temperate humid and Mediterranean zones, but also sports fields and agricultural improved and reseeded grasslands (Davies *et al.* 2004). The *CLempN* from ‘E2.2 low and medium altitude hay meadows’, is not the best representative for the whole E2 group. However, no better *CLempN* information is available and therefore this *CLempN* range was adopted for this whole group.
- No *CLempN* was set for E3. Within ‘E3: Seasonally wet grasslands’ a gradient of nutrient availability exists. E3.51 and E3.52, for which *CLempN* were set by Achermann & Bobbink, (2003), represent oligotrophic systems and are not representative for whole E3. Other systems in this group are generally more eutrophic or Mediterranean (i.e. potentially higher *CLempN* due to higher nutrient turnover and longer growing seasons).
- In E5 woodland fringes and clearings and tall forb stands many different circumstances (nutrient availability and wetness) are grouped. In addition, no *CLempN* information is available for this class. Therefore no *CLempN* was set.

Heathland, scrub and tundra habitat (EUNIS class F)

- For F4 *CLempN* are distinguished on the second and third level. F4 represents wet, dry and macaronesian heaths. The macaronesion have probably higher *CLempN* values than wet and dry heaths for which *CLempN* are known. However, across Europe wet and dry heaths are more present. Since no different classes within F4 can be distinguished on the land cover map, we suggest setting the *CLempN* for this habitat type to the lowest *CLempN* range for the combined group.

In some cases no appropriate *CLempN* range could be adopted. For some EUNIS classes for which CL analysis is sensible, one could, however, choose to add the minimum value of the available *CLempN* information for this class. A maximum *CLempN* can, however, not be set. Absence of any *CLempN* will result in no evaluation for exceedance of nitrogen deposition of a habitat at all, though it is to some level sensitive to nitrogen deposition (Hettelingh, personal comment 2007). The minimum *CLempN* -values are added in brackets in Table 6-1.

Assigning CLempN to the land cover map to create a European background database

For each continuous region of the land cover map, the minimum and the maximum *CLempN* from Table 5.3, or if the differentiation does not apply, Table 6-1 can be assigned as the critical load. This way, two datasets are created, the minimum and the maximum *CLempN*. The datasets are onwards referred to *EmpBGMin* and *EmpBGMax*. Maps of the 5^{th} percentile of each dataset are shown in Figure 6-6. For this maps EUNIS-classes B and C were not included, since for these classes no maximum had been determined The lowest *CLempN* are found in the mountainous areas, in Scandinavia and western Ireland.

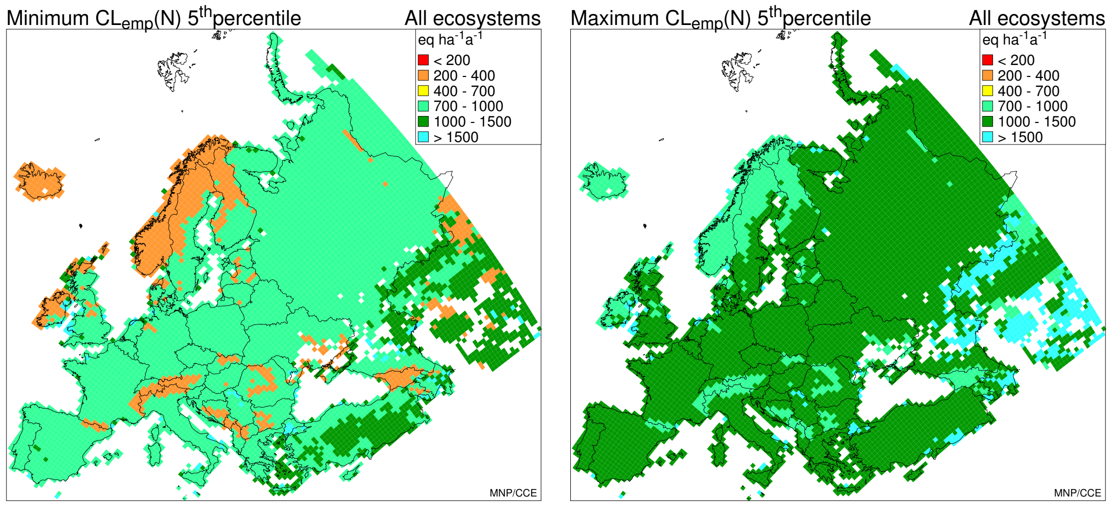


Figure 6-6. *Minimum (left) and maximum (right) CLempN -map (EMEP-grid, 5^{th} percentile).*

Comparison with methodology of SEBI-project

On 22 November 2006 the methodology of adaptation of the European empirical critical loads to EUNIS classes of the land cover-map and the differentiation of the *CLempN* ranges across Europe was discussed with A. van Hinsberg, MNP, Bilthoven, Netherlands. Van Hinsberg is working at the National Focal Centre of the Netherlands and has done a comparable analysis for Dutch habitats as part of the SEBI-project. The approach of applying empirical critical loads to EUNIS classes of the SEI-map and the differentiation of the *CLempN* ranges across Europe was comparable between our and the SEBI-project.

The NFCs have more detailed information available on different habitats than are present on the land cover map. In addition to the *CLempN* from Achermann and Bobbink (2003), A. van Hinsberg applied also the formulated *CLempN* from Dorland and Bobbink (2005). To differentiate within the *CLempN* ranges in the Netherlands Van Hinsberg applied a model in which temperature difference, hydrology, soil properties, etc were put. The outcome of this model determined the height within the *CLempN* range. The approach followed in this project is comparable. Application of the forest *CLempN* from Dorland and Bobbink (2005) in this study would improve the result only slightly, since only limited EUNIS classes are described. However, these *CLempN* have not yet been set officially. The use of biogeographical regions, as a basis for temperature differences across Europe is a good alternative approach. Adding base-cation availability would enhance the possibility to differentiate the *CLempN* range more accurately. Good maps on temperature/frost period and soil properties are available at CCE. Van Hinsberg also formulated the wish to differentiate *CLempN* ranges in smaller steps, to stimulate the use of empirical critical loads across NFCs in Europe. However, since several factors influence the prevailing *CLempN* for a specific habitat, an exact value for a specific biogeographical region is inappropriate. In addition, these *CLempN values* are based on scientific research that has a certain variation.

6.5 Comparison of the critical loads

General

We compared the empirical critical loads from the land cover map (minimum and maximum of the ranges, EmpBGmin and EmpBGmax respectively, see previous paragraph) with the critical loads from the NFCs. Figure 6-7 shows the EMEP50 grid minimum of EmpBGmin, the grid maximum of EmpBGmax, and the grid minimum of the modelled and the empirical critical load of nitrogen. The three maps with empirical critical loads show similar regional distributions of relatively low and high values.

From the NFCs modelled critical loads as well as empirical critical loads were available from a 2007 call. So, we compared the *CLempN* from the land cover map with both the *CLnutN* and *CLempN* from the NFCs submissions. The comparison was made in two steps. Firstly, we checked whether the *CLnutN* and *CLempN* from the NFCs are within the *range* of the *CLempN* of the land cover map. Secondly, we compared the minimum values of critical loads for nitrogen for each of the EMEP50 grid cells.

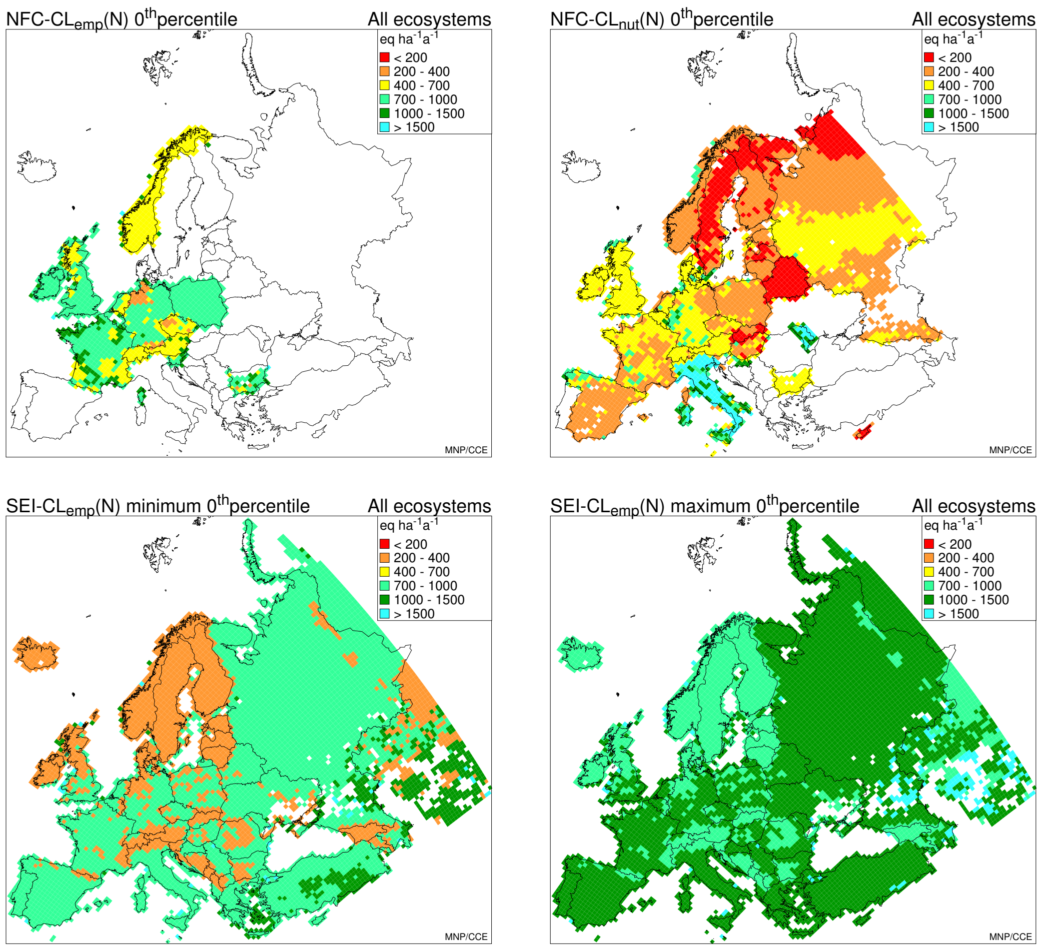
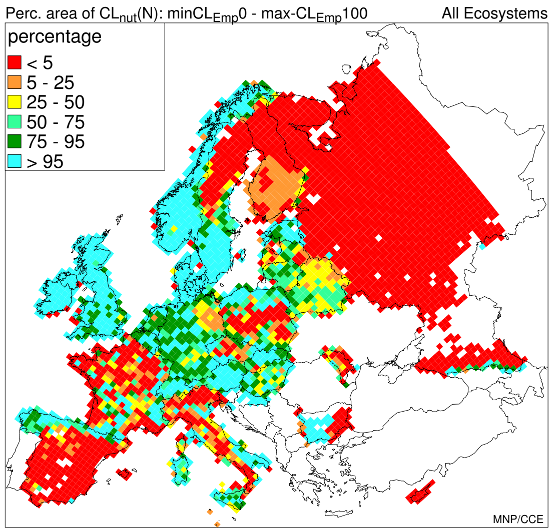


Figure 6-7. *Minimum (0^{th} percentile) of CLnutN and CLemp of the NFC submission (top row), the 0^{th} percentile of the minimum of the land cover derived empirical load ranges (EmpBGmin, bottom left)) and 100^{th} percentile of the maximum of the land cover derived empirical load ranges (EmpBGmax, bottom right).*

Check CLnutN of NFCs within range of CLempN of land cover map

A first comparison is made between the critical loads of the NFCs and the empirical critical loads from the SEI-map at the level of EMEP50 grid cells. For this comparison we used the lowest and highest CLempN per EMEP50 grid cell as range. EUNIS-classes B and C were excluded from this analysis, because for these classes no maximum could be derived (see Table 6-1). In Figure 6-8 (left) the percentage of NFC-sites with critical load values within the range of *CLempN* of the land cover map are presented. In north-west and central Europe most of the NFC *CLnutN* values are within the range of the *CLempN* from the land cover map, in contrast to the Mediterranean countries, North Sweden, Finland and Russia. Of course this figure does not indicate whether the NFC *CLempN* is lower or higher than the *CLempN* from the land cover map. Therefore we compared in addition the minimum *CLnutN* from the NFCs with the minimum *CLempN* of the land cover map (Figure 6-8 right), since the minimum critical loads are the most important protection levels to be taken into account.



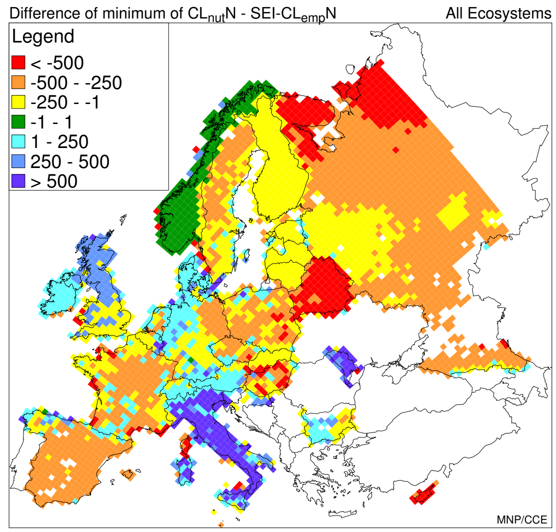


Figure 6-8. *Left: Percentage of NFC-sites of which the CLs lie within the range of CLempN of the land cover map; Right: Difference of minimum critical load (eq ha^{-1} a^{-1}) between the NFC CLnutN and the CLempN of the land cover map.*

From Figure 6-8 (right) it is clear that in most parts of Europe, modelled critical loads are lower than the *CLempN* from the empirical background dataset, except for Italy, Moldavia and parts of the United Kingdom.

We can conclude that in most of Spain, France and the North-East part of Europe the modelled critical loads are much lower then the empirical critical loads from land cover dataset, and in Italy and Moldavia much higher values are found for modelled critical loads.

Check *CLempN* of NFCs within range *CLempN* of SEI-map

In the same way a second comparison is made between the *empirical* critical loads of the NFCs and the empirical critical loads from the SEI-map at the level of EMEP50 grid cells (Figure 6-9 left). In Figure 6-9 (left) we see that the *CLempN* from the NFCs are generally within the range of *CLempN* from the land cover map. This could be expected because all *CLempN* were derived from the same scientific source, using the same guidelines. We did an additional analysis by comparing the minimum *CLempN* from the NFCs and the land cover map (Figure 6-9 right). From Figure 6-9 (right) it is clear that the *CLempN* from the NFCs are generally higher than the *CLempN* from the land cover map, probably because most NFCs do not use a minimum but the average *CLempN*.

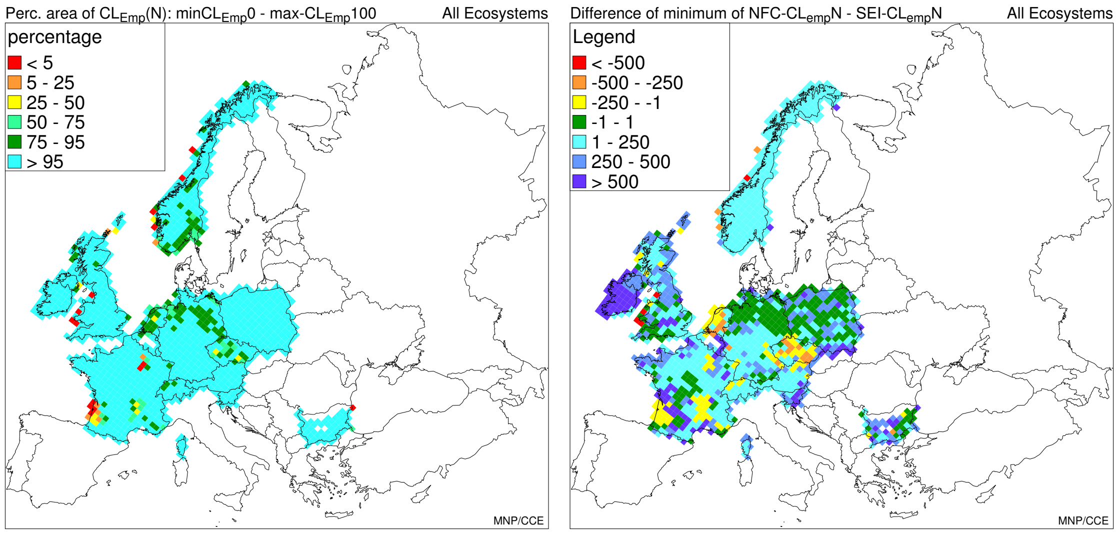


Figure 6-9. *Left: Percentage of NFC-sites of which the CLempN is within the range of CLempN of the SEI-map; Right: Difference of minimum critical load (eq ha^{-1} a^{-1}) between the NFC-CLempN and the CLempN of the SEI-map.*

6.6 Conclusion and recommendations

Conclusions

For the harmonization of the input of the NFCs, European data on critical loads for nitrogen and distribution of ecosystems have been compared with the national input from the NFCs. The European empirical critical loads for nitrogen from Achermann and Bobbink (2003) have been adapted for the critical load calculations. Empirical critical loads are lacking or not yet available for a large number of ecosystem types. The necessity and possibilities to derive and diversify information on empirical critical loads are evaluated. In addition a 100 m grid European land cover map have been produced, based on information of SEI, presents information on the distribution of ecosystems according to the second and third level of the EUNIS-classification, the harmonized land cover map. A European critical load map based on the European empirical critical loads and on the land cover map is presented. From the comparison between the distribution of ecosystems according to the NFCs and the land cover map, which was only possible for forest ecosystem, appeared that for a number of countries there is a moderate correspondence in the forest areas, although the spatial distribution of the forest in both maps are similar. From a second comparison between the critical loads from the NFCs and the empirical critical loads from the land cover map, it appeared that there is a reasonable agreement between the two sources and those differences can be explained by the fact that NFCs generally use lower critical loads. As expected, there is a good correspondence between the empirical critical loads assigned by the NFCs and the land cover map.

Recommendations

The first group of recommendations focuses on the availability of information and use of empirical critical loads:

A large number of empirical critical loads are missing or not yet available. The research and derivation of empirical critical loads for the missing ecosystem types should be continued, for instance for forests, heathland and grasslands.

For the differentiation of empirical critical loads across Europe, additional information should be used, especially the ‘base cation availability’ and ‘temperature/frost period’. The NFCs should use additional information (e.g. P-limitation) to diversify their empirical critical loads.

The empirical critical loads are now produced on basis of all ecosystem types, from (semi)natural to agricultural systems (EUNIS class I and E2.6). We recommend that only semi-natural and natural ecosystems should be considered.

A second group of recommendations focus on the production and use of the European land cover map, the SEI-map:

From the SEI-map no distinction can be made between agricultural and (semi)natural grasslands, which is very relevant from the point of view of critical loads. We therefore recommend that at least this distinction could be made in future maps.

Empirical critical loads are often on the third level (or even lower) of EUNIS-classification and the ecosystem information on the land cover map is on the second level. For a better fit of empirical critical loads and map information we recommend that where possible a third level classification of ecosystems is used on the future maps.

We recommend investigating in depth differences in the assignment of ecosystem types and areas and in CLs between NFCs and the SEI-map and how these differences optimal can be analysed, to support the harmonization-process.

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Annex 6-A EUNIS Classes (Up to level 3) present in the land cover map

Numeric code (E3)	EUNIS CODE list	EUNIS description	Numeric code`(E2) combi
1000	A	Marine habitats	100
1100	A1	Littoral rock and other hard substrata	112
1102	A1 or A2 without A2.5	Littoral rock and other hard substrata or Littoral sediment without Coastal saltmarshes and saline reedbeds	112
1200	A2	Littoral sediment	112
1250	A2.5	Coastal saltmarshes and saline reedbeds	112
1300	A3	Infralittoral rock and other hard substrata	134
1304	A3 or A4	Infralittoral rock and other hard substrata or Circalittoral rock and other hard substrata	134
1349	A3 or A4 or A5	Infralittoral rock and other hard substrata or Circalittoral rock and other hard substrata or Sublittoral rock	139
1400	A4	Circalittoral rock and other hard substrata	134
1500	A5	Sublittoral sediment	105
1600	A6	Deep-sea bed	106
1700	A7	Pelagic water column	107
1800	A8	Ice-associated marine habitats	108
2000	B	Coastal habitats	200
2100	B1	Coastal dunes and sandy shores	201
2200	B2	Coastal shingle	202
2300	B3	Rock cliffs, ledges and shores, including the supralittoral	203
3000	C	Inland surface waters	300
3100	C1	Surface standing waters	301
3102	C1 or C2	Surface standing waters and surface running waters	312
3200	C2	Surface running waters	302
3300	C3	Littoral zone of inland surface water bodies	303
4000	D	Mires, bogs and fens	400
4100	D1	Raised and blanket bogs	401
4200	D2	Valley mires, poor fens and transition mires	424
4204	D2 or D4	Valley mires, poor fens and transition mires or Base-rich fens and calcareous spring mires	424
4300	D3	Aapa, palsa and polygon mires	403
4400	D4	Base-rich fens and calcareous spring mires	424
4500	D5	Sedge and reedbeds, normally without free-standing water	405
4600	D6	Inland saline and brackish marshes and reedbeds	406
5000	E	Grasslands and lands dominated by forbs, mosses and lichens	500
5100	E1	Dry grasslands	501
5109	E1 without E1.2, E1.7, E1.8, E1.9, E1.A	Dry grasslands without Perennial grasslands and basic steppes or Non-Mediterranean dry acid and neutral closed grassland or Non-Mediterranean dry acid and neutral closed grassland or Mediterranean dry acid and neutral closed grassland or Mediterranean dry acid and neutral open grassland	501
5120	E1.2	Perennial grasslands and basic steppes	501
5179	E1.7 or E1.9	Non-Mediterranean dry acid and neutral closed grassland or Non-Mediterranean dry acid and neutral closed grassland	501
5189	E1.8 or E1.A	Mediterranean dry acid and neutral closed grassland or Mediterranean dry acid and neutral open grassland	501
5200	E2	Mesic grasslands	502
5209	E2 without 2.3	Mesic grasslands without Mountain hay meadows	502
5230	E2.3	Mountain hay meadows	502
5300	E3	Seasonally wet and wet grasslands	503
5400	E4	Alpine and subalpine grasslands	504
5500	E5	Woodland fringes and clearings and tall forb stands	505
5600	E6	Inland salt steppes	506
5700	E7	Sparsely wooded grasslands	507
6000	F	Heathland, scrub and tundra	600
6001	FA	Hedgerows	610
6002	FB	Shrub plantations	611
6100	F1	Tundra	601
6200	F2	Arctic, alpine and subalpine scrub	602
6300	F3	Temperate and Mediterranean-montane scrub	603
6400	F4	Temperate shrub heathland	604
6500	F5	Maquis, arborescent matorral and thermo-Mediterranean brushes	656
6506	F5 or F6	Maquis, arborescent matorral and thermo-Mediterranean brushes or Garrigue	656
6600	F6	Garrigue	656
6700	F7	Spiny Mediterranean heaths (phrygana, hedgehog-heaths and related coastal cliff	607
6800	F8	Thermo-Atlantic xerophytic scrub	608

Numeric code (E3)	EUNIS CODE list	EUNIS description	Numeric code`(E2) combi
6900	F9	Riverine and fen scrubs	609
7000	G	Woodland, forest and other wooded land	700
7100	G1	Broadleaved deciduous woodland	701
7300	G3	Coniferous woodland	703
7400	G4	Mixed deciduous and coniferous woodland	704
7500	G5	Lines of trees, small anthropogenic woodlands, recently felled woodland, woodland and coppice	705
8000	H	Inland vegetated or sparsely vegetated habitats	800
8100	H1	Terrestrial underground caves, cave systems, passages and water bodies	801
8200	H2	Screes	802
8300	H3	Inland cliffs, rock pavements and outcrops	803
8400	H4	Snow or ice-dominated habitats	804
8500	H5	Miscellaneous inland habitats with very sparse or no vegetation	805
8600	H6	Recent volcanic features	806
9000	I	Regularly or recently cultivated agricultural, horticultural and domestic habitats	900
9100	II	Irrigated arable land	901
9100	I1	Arable land and market gardens	901
9200	IN	Non-irrigated arable land	902
9200	I2	Cultivated areas of gardens and parks	902
10000	J	Constructed, industrial and other artificial habitats	1000
10100	J1	Buildings of cities, towns and villages	1001
10200	J2	Low density buildings	1002
10300	J3	Extractive industrial sites	1003
10400	J4	Transport networks and other constructed hard-surfaced areas	1004
10500	J5	Highly artificial man-made waters and associated structures	1005
10600	J6	Waste deposits	1006
24000	X	Habitat complexes	2400
25000	Y	Unknown	2500